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Case report
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Application of Value Stream Mapping in Pump Assembly Process: A Case Study

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Abstract

Over the decade, there has been increasing interest in the leaner and more responsive operations along with reduction in Cycle time to improve performance across the entire business network. "Process Improvement" means making things better. However, when we engage in true process improvement, we seek to learn what causes things to happen in a process and to use better technology to reduce product variation, remove activities that contribute no value to the product or service produced, and improve customer satisfaction. To examine all of the factors affecting the process in related with men, machine and materials are main responsible for the transformation of materials in to a product or service. Lean manufacturing is originated and developed in Japan which is considered as a business strategy to reduce and eliminate wastes occurred during manufacturing process, thus it leads to improve the productivity by giving quality products with higher accuracy especially for small and medium scale enterprises (SMEs) To implementing lean approach, VSM (value stream mapping) and kaizen principles are most effective in nature among all other lean practices. In this research work, a case study on implementing VSM and kaizen as the lean manufacturing initiative is clearly reported. And the same lean tools are implemented in pump assembly of medium scale enterprises to identify and reduce the wastes during this case study. Here initially process path is visualized by drawn current value stream mapping (CVSM), after tracking the entire process wastes affecting the cycle time are identified and analyzed. In the next stage, the application of Kaizen principle to reduce the wastes in the process, then future state map is developed to analyze the previous cause for the waste development. This capability will definitely enable the considering enterprise to achieve cycle time reduction, competitive strength and productivity.

Keywords: Lean manufacturing tools; Value stream mapping; kaizen; Cycle time; Productivity

Introduction

Contemporary competition has forced companies to innovate innovative things on day by day process to change their manufacturing culture. For this reason the enterprises are moving towards the advanced manufacturing techniques like lean manufacturing, supply chain management, agile manufacturing concurrent engineering are most popular in nature to satisfy the customer requirement competitively. In this regard reducing waste in manufacturing process will definitely results in good productivity with shorted cycle time. Among all the technologies, the lean manufacturing is most popular waste reduction technique in manufacturing process. Lean is not a just waste eliminating process but built with three strong commandments like be change, live the change and Worship the change [1]. On the other hand, applications of lean manufacturing principles in the continuous process sector have been far fever and more popular examine the aspects of continuous production that are amenable to lean techniques in present a classification schemes are necessary for quality and efficiency of a products [2,3]. Manufacturing becoming a more competitive, companies globally strive to increase their efficiency due to intense competitive pressure due to globalization, hence they cannot afford to operate with waste in their processes, especially needed for the problems of SMEs (small and medium scale enterprises) In order to overcome this difficulties faced by SMEs, the application of lean manufacturing tools is the most essential in manufacturing process. In our case study, the incorporation of value stream mapping (VSM) and kaizen for the pump assembly process in medium scale industry is considered to minimize the waste for getting Productivity is discussed with future aspects is the main scenario of this research work.

Manufacturing activities and its identification

For any manufacturing process there must be wastes, to identify these waste the fallowing steps to fallow:

Identify all the steps along the process chain - This means identifying the value stream, is used to identify activities where value is added to the product

• **Make those processes flow** - The value added product must flow continuously from the start to finish without interruptions, detours, waiting, scrap and stoppages.

• **Make only what is pulled by the customer** - The customer should pull the product from the source as needed rather than pushing the products onto the customer.

• **Strive for perfection** - After implementing above steps the team should be continuously remove wastes as they are uncovered and pursue perfection through continuous improvement.

In any manufacturing process, there are certain important manufacturing activities can appear, as follows

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➢ **Non-value added activities:** are pure waste (MUDA) which involves unnecessary actions like waiting time, stacking intermediate products, or double context these can be eliminated completely,

➢ **Necessary but non-value adding (NNVA) activities**: are wasteful but necessary or mandatory under current operating procedures including walking to pick up parts, unpacking deliveries and transferring.

➢ **Value adding (VA) activities:** Any activity adds the value to a product, while useful to processing of raw materials to semi-finished and ultimately to finished products through the use of manual labor.

To overcome the waste occurred in process the advance manufacturing technique like lean manufacturing and its tools are most effective and in next its importance are discussed in next topic.

Overview of lean manufacturing

Lean production was introduced by Toyota on the basis of JIT principle in 1960's to eliminate waste, reduce inventory and setup times, which is a systematic approach to identify and eliminate waste through continuous improvement throughout all manufacturing processes and making the product to pulling towards the customer with perfection [4]. Lean focuses on eliminating all non-value added activities from order of entry to receipt of payment, lead time and work in process reduction (WIP), quality improvement, enhanced flexibility, reduced transactions, simplified scheduling, improved communications, reduced costs, better on time deliveries, increased sales and space utilization are all possible through the effective planning and implementation of lean production[5,6]. Researchers agreed that LM could be a cost reduction mechanism and can be used to guide to be world class organization by its popular tools like 5s, TPM, poka-yoke, kanban, cellular manufacturing SMED, kaizen, value stream for the better productivity, reduction in WIP inventory, improvement in quality, reducing space utilization and better work place organization. Identifying what creates value for customers. The Lean approach can be summarized Specify what creates value from the customer's perspective, while in process, if customer does not pay for non-value added activities and should be eliminated from the process [7].

Literature Review

VSM is one of the most important and powerful Lean tool for an organization to implement and improve on its lean journey. The car manufacturer Toyota co. Japan was the first company to use VSM techniques in its lean concepts implementation. VSM has been thoroughly analyzed and a team created to improve the productive system of a manufacture application, it is a graphical tool which is created using a predefined set of standardized icons that helps the organization to see and understand the flow of material and information as the product goes along different stages [8]. After drawing the value stream it helps the organization to differentiate value adding activities from non-value adding activities from current condition and identify kaizen opportunities. The real benefit is, it gets the company away from isolated point kaizen and builds towards a true system based on the flow of materials and information across the entire value stream, modification of inner wheel housing process line by considering case study of an automobile industry with effective cycle time reduction is made clearly, assembly lines are still fundamental to get the smoothing of production system in any medium organization [9-11]. Explanation of VSM application tool which provides communication solutions for practitioners to obtain maximum efficiency and definitions of theoretical development points to become a reference among redesign techniques [12]. By practicing VSM, elimination of waste and streamlining the business is very effective by implementing fallowing stages of VSM techniques like Identify what product or family of products to be mapped, draw the current state map, identify where the improvements can done to eliminate waste finally draw the future state map.

VSM in global contest

In this section literature survey is carried out, to explore how VSM is adopted to SMES of different organizations in global context and its usages. The development and application of VSM to supplier network of electronic, electrical and mechanical components for a distributor were studied [13]. Explanation of VSM approach in manufacturing and service settings including administrative processes made as remark [14]. VSM is an excellent tool for any organization that wants to become lean [15]. Study of VSM highlighting process inefficiencies, transactional and communication but also guides the improvement by application of current and future maps [16]. VSM and other Lean principles were adopted at a large integrated steel mill in India to improve the process [17]. The degree to which responses customer orders as needed in flexible, quick and low cost from one member of a product family to another through Leanness, VSM is a suitable tool for redesigning the production system of a plastic casing mobile phone manufacture based on global review [18]. VSM helps in usage levels of shop floor practices aimed at increased human and machine productivity [19]. Study on wait time and service time for patients visiting emergency rooms was focused and got succeeded in hospital case study [20]. Planning, preparation and identifying the target process, product family or service through mapping team were explained [21]. VSM process symbols were used to discuss lean implementation stages in the auto-parts manufacturing unit [22]. Investigation related to difficulties and limitations during the application of VSM technique were analyzed on the global review, VSM applications on SMES are limited, so implementation of VSM to eliminate non-value added activities in SMES through the case study is the main motive of this work [23].

VSM symbols

The VSM symbols and terminologies to prepare current and future value stream mapping are given in the following Table 1 and Table 2 respectively.

Here this paper describes the identification of several gaps and shows how VSM actions can achieve with higher performance in shorter cycle time by using real data's in pump assembly line with more flexibility.

Company and process background

Weir Minerals India Pvt. Ltd is a subsidiary unit of Weir group PLC, where the case study is carried out. In 1871, two brothers, George and James Weir, founded the engineering firm of G&J Weir. Indian operation was started in 1992, at Peenya industrial area, Bangalore, India. Weir is focused on delivering engineering solutions to customers in the minerals, oil and gas and power markets. The company is structured into three divisions. Weir minerals are manufactures of slurry pumps, valves, hydro cyclones and mill lining systems for the mining and mineral processing industries, valves and engineering support for the oil and gas industries.

Problem Description

In recent years, lean manufacturing has been widely practiced normally in large scale industries. However its implementation in small

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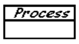
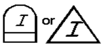
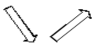
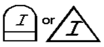
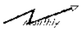
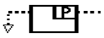
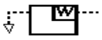
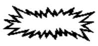
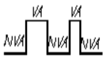
Symbol	Description
 Customer/Supplier	Used to show customers, suppliers and outside manufacturing process
 Dedicated Process	This icon is a process, operation, machine or department, through which material flows.
 Data Box	Which carries customers, department and manufacturing process
 Inventory	This shows inventory between two process
 Shipments	This icon represents movement of raw materials from suppliers to the Receiving docks of the factory. or the customers
 Inventory	This shows inventory between two process
 Push Arrow	This icon represents the "pushing" of material from one process to the next process.
 Material Pull	Pull of materials from Supermarkets.
 External Shipment	Shipments from suppliers or to customers using external transport.
 Manual Info	A straight, thin arrow shows general flow of information from memos, reports, or conversation..
 Electronic Info	This wiggle arrow represents electronic flow such as electronic data interchange (EDI), the Internet, Intranets, LANs, WANs
 Production Kanban	This icon triggers production of a pre-defined number of parts. It signals a supplying process to provide parts to a downstream process.
 Withdrawal Kanban	This icon represents a card or device that instructs a material handler to transfer parts from a supermarket to the receiving process.
 Signal Kanban	It signals a changeover and production of a predetermined batch size of the part noted on the Kanban.
 Go See	Gathering of information through visual means.
 Kaizen Burst	These icons are used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving the FSVSM
 Operator	This icon represents an operator. It shows the number of operators required to process the VSM family at a particular workstation.
 Timeline	The timeline shows value added times (Cycle Times) and non-value added (wait) times. Use this to calculate Lead Time and Total Cycle Time.
 Verbal Information	This icon represents verbal or personal information flow.
 Sequenced Pull	This icon represents a pull system that gives instruction to subassembly processes to produce a predetermined type and quantity of product
 Load Leveling	This icon is a tool to batch kanbans in order to level the production volume and mix over a period of time
 MRP/ERP	Scheduling using MRP/ERP or other centralized systems.

Table 1: VSM symbols.

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Terminology	Description
Takt time	The rate at which a company must produce a product to satisfy its customer demand. It is calculated by dividing available working time per day (in minutes or seconds) to customer demand per day (in relevant units) TAKT time= Available working time per shift / Customer demand per shift
Lead / Production lead-time	The amount that elapses between when a product starts when it is completed / it is a total time, when a component takes in its way through a shop floor beginning with arrival of raw material to finished goods to customer
Cycle time	It is the period task to complete one cycle of an operation that elapses between when the process starts to its completion. For typical process operation like machining, assembly. The cycle time (Tc) consists of actual machining operation(To), work part handling time(Th), and Tool handling time(Tth) Where Tc=To+Th+Tth
Through put time / Mfg. process run time	It is a time required for material, part or assembly to pass through the process
Value added time	It is the time which is utilized in adding actual value to the product
Non value added time	Is a Pure waste (Muda), which involves unnecessary actions like waiting time, staking intermediate parts, double handling, searching for tools etc.. hence should be eliminated completely with in the manufacturing process.
Current state map	It describes existing/current position of shop floor of any manufacturing facility
Future state map	It describes the proposed/ future position of shop floor of any manufacturing facility in order to being some improvement
Pull production	Producing components exactly at the place of customer requirement
Kanban	Is a Japanese word, Kan means visual, Ban means card / board, The term implies to inventory control method, that cards are used to signal the need for an item
Kaizen	Kai stands for take part and Zen for make good , the term denotes the change for better, it is an adequate process improvement and quality strategy to eliminate waste in the process through the modifications in the process by scientific methods

Table 2: VSM terminologies.

and medium enterprises (SME's) with lean applications is limited and is challenging for the operators and higher level management people due to new industrial culture and adoptability of new changes in work environment. Hence the present work focuses on the investigation and study of existing problem of slurry pump assembly area in wear minerals India (P) Ltd, Bangalore, a medium scale enterprise, here the current problem is delay in pump assembly due to shaft sleeve availability form the supplier in time and some process problems in assembly line, pump assembly process is shown in Figure 1.

In pump assembly, the process deviation takes place and rejections of the shaft sleeves occurs, for which reduction of through put time is essential through the study of route cause analysis. Hence this work deals with the end to end perspective of reducing waste at an assembly line of a pump of a construction equipment manufacturing company. The model and details of drawing for which is shown in Figures 2 and 3.

Cause and effect relationships

The cause and effect analysis diagram is shown in Figure 4 below and for the delay of supply of shaft sleeve to the pump assembly reasons are shown and the main issues are discussed in objectives.

Objectives

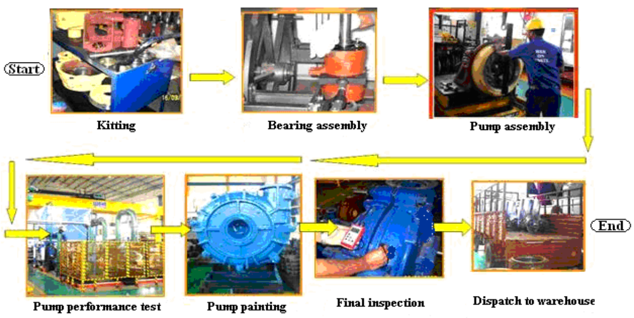

Figure 1: Pump assembly process.

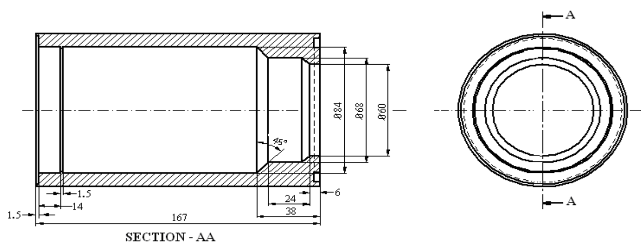

Figure 2: Shaft sleeve detail drawing.

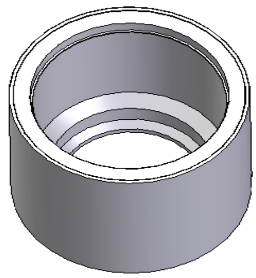

Figure 3: Shaft sleeve model.

Today, suppliers have a great concern over improving quality and delivery and decreasing cost, which leads to improved system productivity. In order to remain competitive, non-value added activities must be identified and by using effective lean tool like VSM and same can be eliminated in order to run system with maximum efficiencies. In this research work our aim is to investigate the non-value added activities in pump assembly process that will most significantly impact the assembly of pump system delay, here the NVA activities are identified in the pump process then these can be eliminated completely through the application of Lean tools like VSM, and Kaizen principles. The main objectives are identifying non value added activities in the

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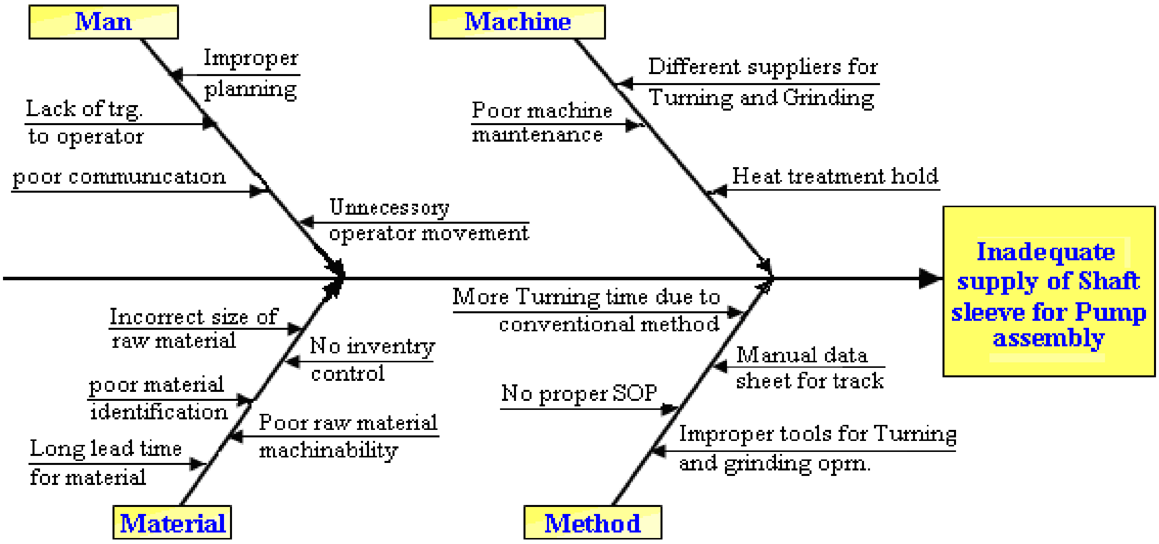

Figure 4: Fish bone diagram for pump assembly.

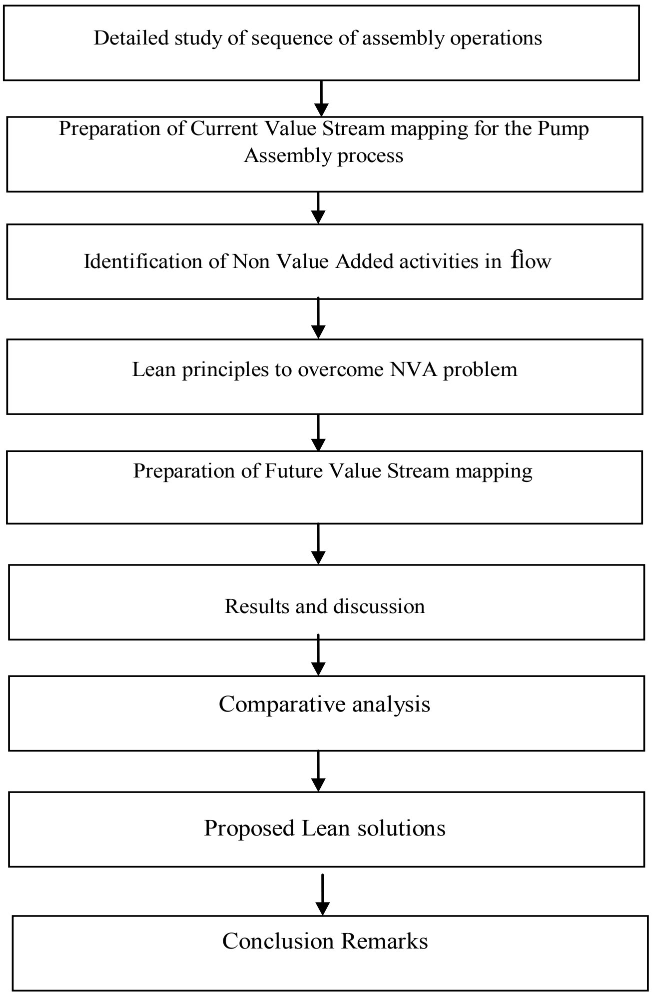

Figure 5: Methodology.

pump assembly line using Value Stream Mapping (VSM) techniques and apply the Lean principle like Kaizen to pump assembly process, and then FSVSM is made to show the reduction of throughput time in assembly of pump.

Methodology

To start improving productivity by identifying waste in the pump assembly process and then removing it by implementing suitable effective lean principle in the process, in our case study VSM (Value Stream Mapping) is the better visualization tool to identify NVA in the process, then the FSVSM can made through the application of Lean principles for decreasing through put time. The methodological process steps as shown in Figure 5.

Data Collection, Analysis and Solution

For any process improvement of its techniques are very essential. On the basis of data fact and figure users only we are moving towards improvement, to improve the total process time of shaft sleeve we referred the data's from suppliers, andon register, total sales book, heijunka compliance register. The process considering process activities are shown in Tables 3-6.

Processing of the data for analysis

PROCESS FLOW CHART
(TITLE: VSM OF SHAFT SLEEVE)

S.No.	Activities	Dist.	Time	People	OPERATION	TRANSPORTN.	INSPECTION	DELAY	STORAGE
A4	**Supply of raw material to supplier**								
1.	Refer the purchase order	0	5	1					
2.	Confirm the order booking		5	1					
3.	Issue the plan for production		15	1					
4.	Refer the cutting size , etc		15	1					
5.	Refer stock in go down		15	1					
6.	Ensure the raw material in go down		45	1					
7.	Inspect the raw material		45	1					
8.	ensure the correct raw material		30	1					
9.	Raw material pull from store	100	100	2					
10.	Move to cutting machine	20	30	2					
11	Start the machine		30	2					
12	Set the machine to cutting size		15	1					
13	operation starts		240	1					
14	Take the cutted raw material		30	1					
15	Check he raw material		15	1					
16	Stop the machine		5	1					
17	Take raw material to store		30	1					
18	Excess rod move to store	25	45	2					
19	Invoice the raw material		45	1					
20	Book the transporter		30	1					
21	Waiting transporter		15	1					
22	Load the material to transport	100	300	1					
23	Refer LR copy		30	1					
24	Send the LR copy to supplier		5	1					
25	Receive the material	100	265	2					
	Total time in A4 activity		**25 hrs.**						
	Gap of receiving material to inward		25						
A5	**Inward inspection of raw material**		**0.10**						
1	Unload the raw material by stores	20	60	1					
2	Check the invoice with raw material		15	1					
3	Inward the raw material GRN	30	15	1					
4	Inspect the raw material quality		15	1					
5	Ensure the size of the shaft sleeve		15	1					
6	Refer test certificate		15	1					
7	Identified with color code		15	1					
	Total time of A5 activity		**2. 5 hrs.**						

Table 3: Process Flow Chart for A4 and A5 activities.

PROCESS FLOW CHART (TITLE: VSM OF SHAFT SLEEVE)

S.No.	Activities	Dist.	Time	People	OPERATION	TRANSPORTN.	INSPECTION	DELAY	STORAGE
A9	**Turning operations**	0	10	1					
1.	Take the raw material		10	1					
2.	Take the drawing from list		15	1					
3.	Refer the drawing		15	1					
4.	Hold on machine		20	1					
5.	Start turning , set tool in machine		10	1					
6.	Facing		15	1					
7.	Drill bit set the tail stock		30	1					
8.	start drilling		45	1					
9.	Start boring		20	1					
10.	Start OD turning		25	1					
11	Reverse the job		15	1					
12	Hold the job		45	1					
13	Start next side turning		10	1					
14	Set the tool post for taper turning		25	1					
15	Start taper turning		10	1					
16	Set the tool to internal taper turning		20	1					
17	Start taper turning		35	1					
18	Reverse the job for second side		20	1					
19	Set the tool for taper turning		15	1					
20	Start taper turning		20	1					
21	Inspect proof machined shaft sleeve		15	1					
22	Unload the shaft sleeve		15	1					
23	Keep shaft sleeve in inspection area		30	1					
	Total time of A5 activity		**8 hrs.**						

Table 4: Process flow chart for a9 activity.

PROCESS FLOW CHART (TITLE: VSM OF SHAFT SLEEVE)

S.No	Activities	Dist.	Time	People	OPERATION	TRANSPORTN.	INSPECTION	DELAY	STORAGE
A11	**Heat Treatment Operation**	0							
1.	Move to heat treatment operation area	200	45	1					
2.	Make the parts		5	1					
3.	Call transporter	20	30	1					
4.	Pick up the raw material	8	15	1					
5.	Move the parts to heat treatment ship	100	40	1					
6.	Plan for heat treatment		20	1					
7.	Load for heat treatment	5	20	1					
8.	heat treatment operation		900	1					
9.	Unload shaft sleeve from heat treat. tre	5	30	1					
10.	Leave the material for cooling		230	1					
11	Take the party for inspection	5	15	1					
12	Move the part to dispatch area	45	30	1					
13	Generate invoice		15	1					
14	Arrange the vehicle		15	1					
15	Move the shaft sleeve	40	45	1					
16	Inward the shaft sleeve	5	15	1					
17	Inspect the shaft sleeve		30	1					
	Total time of A5 activity		**25 hrs.**						

Table 5: Process flow chart for a11 activity.

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PROCESS FLOW CHART (TITLE: VSM OF SHAFT SLEEVE)					OPERATION	TRANSPORTN..	INSPECTN.	DELAY	STORAGE
S.No.	Activities	Dist.	Time	People					
A19	Assembly	0							
1.	Hold the shaft between fixture		5	1					
2.	Insert green retainer		5	1					
3.	Fix bearing on shaft	2	5	1					
4.	Press bearing on shaft	2	2	1					
5.	Insert another sealing on shaft	1	5	1					
6.	Fix roll on wet end of shaft	2	5	1					
7.	Place end cover on skin and bolt	5	2	1					
8.	fix end retainer with hole		2	1					
9.	Fix and tighten end cover		10	1					
10.	Select the work station	5	5	1					
11	Fix inspection bar and fixture	5	5	1					
12	Use pneumatic wrenches	5	5	1					
13	Note the part number	2	2	1					
14	Punch the sealing	2	2	1					
15	Set the CTQ with assembly	5	5	1					
16	Do the hydro test	5	5	1					
17	Remove the assembly	10	10	1					
18	Move to painting area		5	1					
	Total time of A5 activity		1. 40 hrs						

Table 6: Process flow chart for a19 activity.

From the above data collected we have identified areas for development to reduce the through put time of shaft sleeve. We have taken 8/6 EAH pump shaft sleeve taken which is a medium sized pump and having 181 pumps and as per records from marketing survey we have more orders in the pipe lines, so we have to consider this pump for analysis and we can deploy this horizontally for all type of pumps. The current state process and related value stream mapping of E076 C21 shaft sleeve as shown in Table 7 and Figures 6 and 7.

Calculations

Percentage of NVA Time=Total NVA time in days/Total processing time in days × 100

=134.4/241.7 × 100

=55.6%

Percentage of VA Time=Total VA time in days/Total processing time in days × 100

=24.3/241.7 × 100

=10.05% (Figures 8 and 9)

Lean implementation through kaizen principle and development of future VSM

Kaizen principle: Continuous improvement of an entire value steam or an individual process to create more value with less waste. There are two levels of kaizen. System or flow kaizen focuses on the overall value stream. Process kaizen focuses on individual processes. Kaizen is a Japanese term which means a change of wisdom for continuous betterment. Only daily incremental modification based on scientific method can bring about a great success in every sphere of workplace. Kaizen means a constant effort not only to maintain but also to upgrade standards, which pronounces perpetual development

Current State Process of Shaft Sleeve		
Activities	**Process**	**Sub process**
A1	Purchase schedule to supplier	
A2	Purchase order entry	
A3	Purchase order to raw material supplier	
A4	Supply of raw material to supplier	
A5	Inward inspection of raw material	
A6	Moved to stores	
A7	Plan for production / Moved to production	
A8	Cut the required size of raw material	
A9	Turning operation	
		Holding the job in lathe
		Facing
		Drilling
		Boring
		OD turning
		ID turning
		ID taper turning
	Total time for Lathe operation	
A10	Inspection	
A11	Heat treatment operation	
A12	Grinding operation	
		OD grinding
		ID grinding
	Total time for Grinding operation	
A13	Groove turning	
A14	Inspection	
A15	Packing	
A16	dispatch	
A17	Inward inspection	
A18	Kitting	
A19	Assembly	

Table 7: Process activities of shaft sleeve.

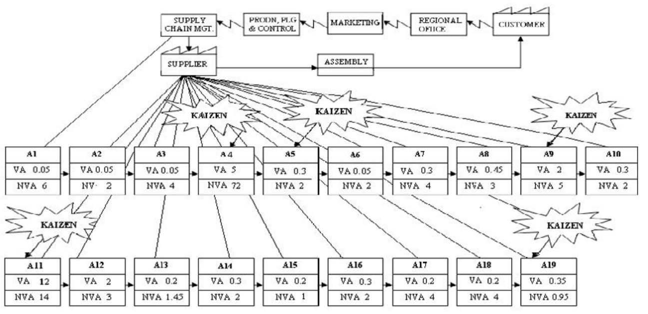

Figure 6: Current state map.

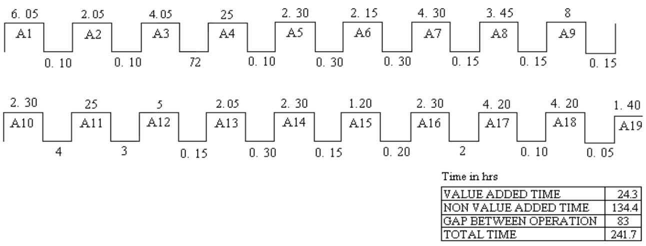

Figure 7: Time line diagram of current state map.

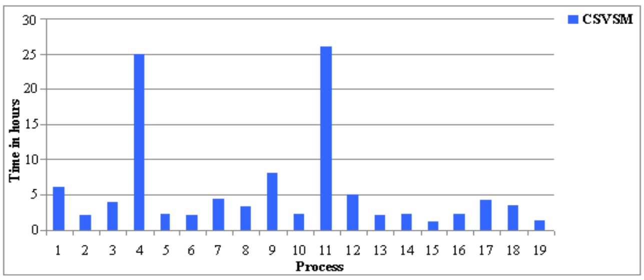

Figure 8: Graphical representation of current state VSM (bar chart).

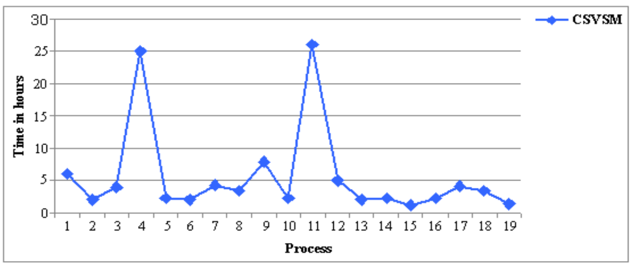

Figure 9: Graphical representation of current state VSM (line chart).

in all walks of our life. Kaizen shows a lead role for improving the productivity and quality of the products. Kaizen is a strategy to include concepts, systems and tools within the bigger picture of leadership involving people and their culture all driven by the customer [24]. The brain storming analysis of VSM revealed the following major NVA identified as operator's movement and their skill, poor process, delay in material transfer to furnace and cooling time in heat treatment for which the proposed lean solutions are suggested as fallows. Table 8 and Figures 10 and 11.

Calculations

Percentage of NVA Time=Total NVA time in hours/Total processing time in days × 100

=40.45/148.3 × 100

=27.2%

Percentage of VA Time=Total VA time in days/Total processing time in hours × 100

=29.45/148.3 × 100

=19.85% (Figures 12-15)

Comparative study

The comparison results of reduction of process time given by graphical method after the implementation of VSM with kaizen effect in the shaft assembly process is as follows (Figure 16).

Results and Discussion

After the implementation of lean tools like VSM to the process of pump assembly, the brief overall benefits can be achieved. The total processing time of the shaft sleeve has reduced from 241.7 hours to 148.3 hours (61%), and increased the efficiency in case of inspection, heat treatment and assembly line of pump so that overall quality of the assembly increases with short cycle time for which we suggested the following essential points to the process improvement, in the assembly line of the pump right size of raw material can be ordered and

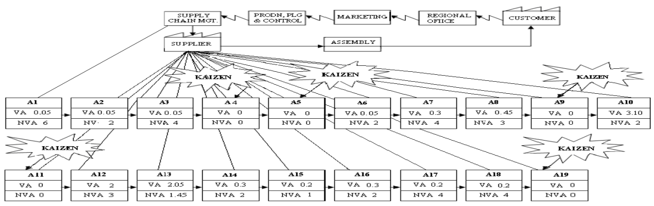

Figure 10: Future State Map.

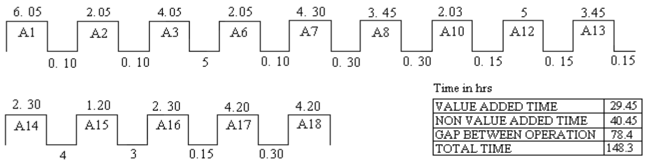

Figure 11: Time line diagram of future state map.

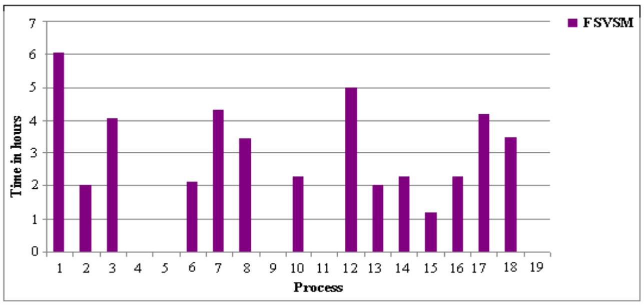

Figure 12: Graphical representation of future state VSM (bar chart).

Activities	Task involved	NVA activities	Proposed Lean solutions to eliminate NVA
A4	Supply of raw materials from supplier	Waiting and transport delays	Collaborative partners, supplier logistic centers, operations through milk van routes Vendor mgt, cross docking
A5	Inward inspection of raw materials	Delays in materials pick ups	Use non-contact inspection
A9	Turning operations	Poor sequence of operations in assembly process	Proper process plan for assembly operations
A11	Heat transfer operations	Loading to furnace unplanned, poor cooling operation	Use mechatronics principle(PLC) for part transfer mechanism and use compressed air for cooling
A14	Assembly	Poor 5s, waiting and operator movement	Use 5s principles for tool arrangements, and quality circles principle for operators

Table 8: Proposed lean solutions.

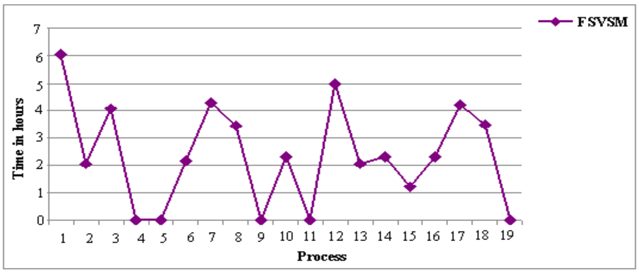

Figure 13: Graphical representation of future state VSM (line chart).

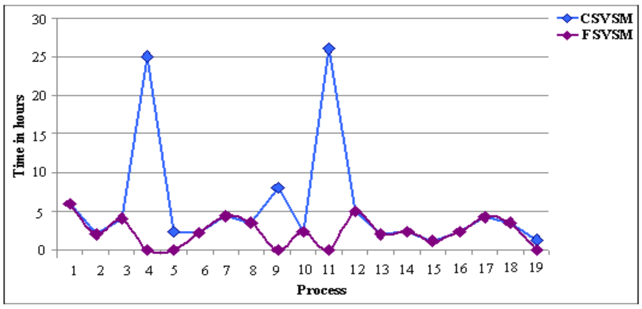

Figure 15: Comparison of CVSM and FVSM for shaft sleeve assembly (line chart).

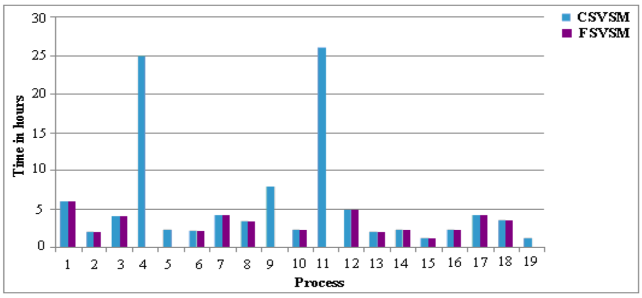

Figure 14: Comparison of CVSM and FVSM for shaft sleeve assembly (bar chart).

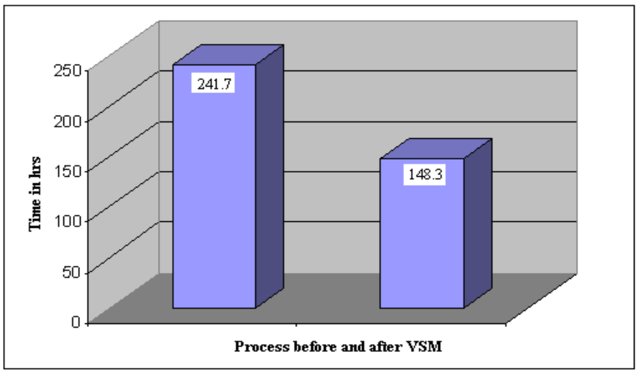

Figure 16: Comparison of process time of shaft assembly.

use automated inspection and cross dock and collaborative partners for suppliers, use mechatronics based PLC principle with transfer mechanism for avoiding heat treatment delays and the use of 5s and quality circles in the assembly decreases its frequent assembly line stoppages. So that by using the lean tools like VSM kaizen and 5s tools we achieved the productivity in the assembly, lesser rejections and more customer satisfaction.

Conclusion

In any manufacturing field the customer satisfaction with varied volumes and varieties of products with competitive price is more essential in modern days. Especially in shop floor elimination of waste and reducing delay time can reflect in market price and complete customer satisfactions. Here the objective is designing low cost process with lesser through put time or cycle time. VSM helps to identify NVA activities in the process thus helps to increase the usage levels by the proficiency of shop floor practices aimed at increased human and machine productivity, so that the process improvement is possible. VSM helps in mapping current and future state maps for the process also, which is the powerful tool for lean manufacturing and allows companies to understand and continuously improve its goals towards lean achievement. It links people, tools, processes and even reporting requirements to achieve lean goals, and provides clear and concise communication between management and shop floor teams about lean expectations. Ultimately the main goal is to identify, demonstrate and decreases the activities that added no value to the final product. But based on practical validation conducted, VSM can be effectively applied to medium scale enterprises as the initial step of waste identification, using this VSM tool, it is possible to map the current status and subsequently analyze waste elimination through Lean principles. Here we discussed the importance of VSM tool to achieve effective process improvement strategy to shorten the cycle time. In our case study, applying VSM tool for the pump assembly in a pump manufacturing industry, a current state map is developed to find the non-value added activities and a future state map is created by eliminating non-value added activities of the process VSM future sate map shows marked improvement in the shaft sleeve for pump assembly process and its through put time is also reduced to 241.7 hours to 148.3 hours, Which demonstrate that any delay can be analyzed through value stream mapping. The present study provides a case study of the improvement of pump manufacturing industry by focusing reducing NVA activities, cycle time and increasing productivity through VSM and kaizen principles, it can be concluded that VSM and kaizen are the effective tool for identifying and reducing the process wastes respectively. By performing the technical suitability, economical justifications and feasibility analysis, we have suggested the recommendations of these tools to induct for the medium scale enterprises confidently.

Future Work

The study can be extended to other parts of the pump; it helps to reduce the total through put time of the pump. It helps to reduce the total manufacturing time of the pump. Researchers can deploy VSM for different ways for several organizations. It is also possible to examine the waste elimination level during different stages and periods, since present study has taken into observations for one single time slot.

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